2001

CONTINUING STUDIES OF ULTRALIGHT AIRCRAFT APPLICATIONS FOR INTRODUCING MIGRATORY POPULATIONS OF ENDANGERED CRANES

KENT R. CLEGG
Grace, ID

JAMES C. LEWIS
University of New Mexico, jclewis@wun.edu

CONTINUING STUDIES OF ULTRALIGHT AIRCRAFT APPLICATIONS FOR INTRODUCING MIGRATORY POPULATIONS OF ENDANGERED CRANES

KENT R. CLEGG, Ultra Air Research, 550 Bench Lago Road, Grace, ID 83241, USA
JAMES C. LEWIS,[1] University of New Mexico, 7712 Midge NE, Albuquerque, NM 87109, USA

Abstract: This research tested whether captive-reared cranes led by an ultralight aircraft (UL) along a migration route, would, after release on a wintering area, integrate with wild cranes and migrate in spring to their natal area without human assistance. This was the historical first motorized migration involving an endangered species. In 1997, whooping cranes (*Grus americana*) and greater sandhill cranes (*Grus canadensis tabida*) were group-reared in species-specific pens and 80% fledged. Beginning 13 October, 4 whooping cranes and 8 sandhill cranes were led along a 1,133-km migration route from Grace, Idaho, to Bosque del Apache National Wildlife Refuge (BdANWR), New Mexico. The migration took 8.5 days with daily flight distances ranging from 27 to 185 km at averages of 52.5 km/hr and 300 m elevation. During migration, 1 whooping crane was injured in an attack by a golden eagle (*Aquila chrysaetos*) and 1 sandhill crane died in an accident with the ultralight (UL). The 11 surviving cranes were released at BdANWR on 21 October. During winter 3 cranes died, 1 killed by a coyote (*Canis latrans*), 1 by a bobcat (*Lynx rufus*), and 1 killed by a hunter. The 8 surviving cranes migrated north on their own initiative in spring, returning to summering areas appropriate for their natal area. Sixty four percent of the released birds survived more than 18 months. We believe the percentage surviving can be increased in future experiments. Whooping cranes can be group-reared, trained to follow experimental aircraft, and will revert to wild behavior on a wintering site in the same manner as captive-reared sandhill cranes released in previous experiments. Basic techniques of training, migration, and introduction to the wild were suitable and show promise for improved use in future reintroductions. Techniques are described for captive rearing, migration, integrating cranes to the wild, and activities post-release.

PROCEEDINGS NORTH AMERICAN CRANE WORKSHOP 8:96-108

Key words: flight training, group rearing, *Grus americana*, *Grus canadensis*, introduction, migration, Rocky Mountains, sandhill crane, whooping crane, ultralight aircraft.

The only self-sustaining wild population of whooping cranes contains about 180 individuals. To promote survival in the wild, the whooping crane recovery plans recommend establishing 2 additional wild populations (Edwards et al. 1994, U.S. Fish and Wildlife Service 1994). In the mid-1990s the Canadian-United States Whooping Crane Recovery Team was evaluating the primary historic nesting habitat in the Canada's prairie provinces to identify a site to reintroduce a migratory population. The source of whooping cranes for the Canadian reintroduction would be captive-reared birds conditioned for wild release.

Juvenile cranes learn a migration pattern and wintering habitat in their first year as they accompany their parents on the annual cycle. This research tested whether captive-reared cranes led by an ultralight aircraft (UL) along a migration route, would, after release on a wintering area, integrate with wild cranes and migrate in spring to their natal area without human assistance.

In 1995, 11 greater sandhill cranes were reared on the Clegg ranch near Grace, southeastern Idaho, trained to follow an UL, led on a 1,200-km migration to central New Mexico, and released to the wild (Clegg et al. 1997). (All research birds are hereafter referred to as UL cranes.) Mortality was high with 2 cranes killed by golden eagles (Ellis et al. 1999), 2 by coyotes, 2 by hunters, and 1 disappeared. The 4 surviving birds associated with wild cranes, imitated their behavior, and migrated north in spring 1996 without human assistance. Two summered within 53 km of their natal area.

Research objectives in 1996 were to refine the techniques and improve survival. Eight sandhill cranes were taught to follow the UL. The migration began 15 October and ended at BdANWR 30 October. Golden eagles were encountered on 4 occasions during migration, but the use of shell crackers to frighten the eagles and, in some instances, pursuit by aircraft, prevented the loss of cranes. The aircraft were grounded 2.5 days in Utah and 3.5 days in New Mexico due to snowstorms. When conditions were suitable for flying, the migration occurred more rapidly than in 1995. All 1996 UL cranes arrived safely at BdANWR.

The day after arrival, it appeared that 2 of the 1996 UL cranes joined several hundred cranes that departed the refuge and headed south, probably to Mexico where large numbers

[1]Corresponding author, e-mail: jclewis@unm.edu

of sandhill cranes winter (Drewien et al. 1992). The other 6 1996 UL cranes integrated with wild cranes and spent the winter at BdANWR along with the 3 surviving 1995 UL cranes.

Individual UL cranes migrated from BdANWR between 27 February and 5 March 1997. Three 1995 and 5 1996 UL cranes were confirmed in the San Luis Valley of Colorado during the 1997 spring migration. Four 1996 and 2 1995 UL cranes were found during the 1997 summer. The 1996 birds were at Grays Lake, Idaho; Downey, Idaho; Bourder, Wyoming; and near Vernal, Utah. One 1995 bird was near Cody, Wyoming, and the other was in Round Valley, Utah, where it also summered in 1996. The 6 cranes did not summer with their UL companions, but all utilized typical crane habitat, associated with wild cranes, and summered in locations normal for cranes hatched in southeastern Idaho.

This paper describes the 1997–98 historical, first migration with whooping cranes. The primary purpose of the research was to determine if the rearing, training, UL migration, and wild-release techniques developed with sandhill cranes would also be suitable with whooping cranes. Crane habitat in the Rocky Mountains is occupied by sandhill cranes, so this research tested whether a flock of captive-reared, endangered cranes, led in migration to an area occupied by wild cranes of another species and released, would learn survival tactics through association with wild cranes.

STUDY AREA

Cranes were raised on the Clegg ranch, which contains a mixture of small ponds, pastures, and fields of alfalfa and barley. The migration route extended southward from Grace through eastern Utah to Moab, across the corner of southwestern Colorado to Cortez, south to Gallup, New Mexico, southeasterly to Los Lunas, and south along the Rio Grande to BdANWR south of San Antonio, New Mexico. This 23,085-ha refuge includes approximately 1,620 ha of managed wetlands and several thousand hectares of corn and alfalfa. Annual peak winter populations of 15,000–20,000 sandhill cranes occur on the refuge.

METHODS

Rearing Technique

Searches for greater sandhill crane nests occurred in late April and May at Grays Lake NWR. Eggs were floated to estimate date of hatching (Westerskov 1950). Twelve eggs with similar hatching dates were removed from nests on 2–3 June, about 4 days before hatching, and kept in an incubator until pipping. As each chick began pipping, the egg was placed in a 1- x 2-m container lined with 5 cm of gravel and wood chips. Two pieces of 0.6- x 0.6-m indoor-outdoor carpet were placed in the container to simulate a nesting platform. Heat lamps above the carpet maintained temperature about 32°C. All 12 sandhill crane chicks hatched. One, appearing weak and not fully developed, died a day after hatching. Two chicks died within the first 10 days of injuries sustained as a result of aggression between siblings. Nine sandhill cranes fledged.

The hatching sandhill crane chicks were placed on the carpet beneath the heat lamp. KRC imitated the brood call periodically during hatching. (The vocalizations promote filial imprinting (Horwich 1996) and the following response needed when the chicks were older.) Attempts to feed the chicks began about 12 hr after hatching. Chicks were offered small moistened pieces of boiled egg whites and night crawlers rolled in Chick Starter Crumbles. Worms in the diet introduced the chicks to a natural food common in the local diet and medication prevented parasite problems. Most chicks were self feeding within 3 days of hatching.

After 2 days the chicks were moved from the container to a 2.4- x 3-m pen inside a building. The floor was covered with gravel and wood chips to create an uneven substrate (Fig. 1). Food and water was available *ad libitum*. Carpet on a raised area in the middle of the pen simulated a nesting platform. A heat lamp above the carpet provided warmth.

Beginning at 2 days of age, sandhill crane chicks were fed early each morning and then taken on walks outside the pen. During the walks, they were fed earthworms to promote natural foraging and to encourage them to eat the natural foods. When the chicks were older, they followed a Polaris all terrain vehicle (ATV) about 0.4 km to a ditch bank in a pasture where they fed on natural foods in the water and uplands. The caretaker left the chicks to forage independ ently.

Fig. 1. Neonatal chicks were group reared on a rough substrate. (Photo by Kent Clegg.)

A full-body crane decoy and the ATV served as attractants in the caretaker's absence. Chicks were observed from a secluded vantage point as they fed on seeds, insects, and earthworms. Potential predators in the area included golden eagles, coyotes, raccoons (*Procyon lotor*), and red-tailed hawks (*Buteo jamaicensis*). Chicks foraged for 2–3 hr or until they appeared restless. Then they were led back to their pen where they fed on commercial food and loafed for the afternoon. In early evening they were again led into the fields to feed.

When the sandhill crane chicks averaged 10 days old, they were moved to a 12- x 30.5-m outdoor pen. A spring-fed stream dividing the pen formed a pond about 3.6-m wide surrounding an island 1.2-m wide (Fig. 2). A metal roof and Plexiglass sides covered the island to protect chicks during inclement weather. Corners of the Plexiglass were open to allow chicks to escape aggression. The chicks waded through water 15-cm deep to reach the island. As the chicks matured, the Plexiglass was removed and the water level was raised to flood the island. Commercial food was available on the island in a bowl. Chicks were viewed periodically through the evening, via video camera, to monitor their well-being.

Whooping crane chicks were initially reared at the USGS Patuxent Wildlife Research Center (Patuxent), Laurel, Maryland, under the direction of KRC and the Patuxent staff. Five eggs of similar hatching dates were removed from the incubator when pipped and placed in a hatcher. KRC imitated the brood call periodically during hatching. After hatching, the chicks were moved to a 1.8- x 6-m indoor pen. Coarse washed gravel was placed on the floor to create an uneven substrate. A carpet-covered mound near each end of the pen simulated a nesting platform. Heat lamps above the mounds provided warmth, and a stuffed model of a crane in brooding posture was placed over each mound. Whooping crane chicks were offered moistened live tadpoles and earthworms (*Lumbricius* sp.) rolled in Chick Starter Crumbles. Live food was placed in bowls of crumbles to encourage self-feeding and an appetite for commercial food. The group was led daily to nearby wetlands where the chicks foraged on natural foods (Fig. 3). Because too few whooping crane chicks of similar age were available, we added 3 whooping crane chicks (17 to 22 days old) from Patuxent's costume-rearing program. Colts were taken on group walks daily to nearby wetlands for 2–3 hr and then returned to their pens.

The 8 whooping crane chicks were transported by private jet aircraft to the Clegg ranch when the younger group averaged 13 days old. One chick died from a coliform bacterial infection 24 hr after its arrival in Idaho at age 34 days. At Patuxent, 2 whooping crane chicks died from a similar infection the same day. Patuxent staff subsequently discovered that the ground water supply, used for the cranes at Patuxent, was contaminated with the bacteria. At the ranch, the 2 groups were combined and the group was placed in an outdoor pen similar to that used by the sandhill cranes. The whooping cranes were led to fields twice daily in the manner described above for the sandhill cranes (Fig. 4).

When the sandhill cranes averaged 29 days old, they were grouped with the whooping cranes for daily exercise. The association of the 2 species was designed to increase the likelihood of association between the whooping cranes and wild sandhill cranes on the wintering grounds. This association was expected to help the UL whooping cranes adjust to the wild.

Sandhill and whooping crane chicks with hatching dates

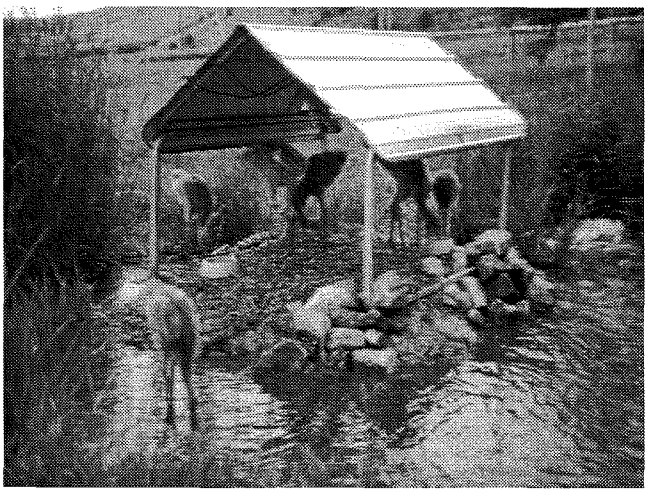

Fig. 2. A flooded island in the rearing pen encouraged the chicks to forage and roost near and in water. (Photo by Kent Clegg.)

Fig. 3. Chicks, even when very small, were led afield to introduce them to wetlands and to encourage them to forage on natural foods. (Photo by Kent Clegg.)

Fig. 4. Two-week-old colts were exercised daily by lengthy treks afield at the Clegg Ranch. (Photo by Frank Clegg.)

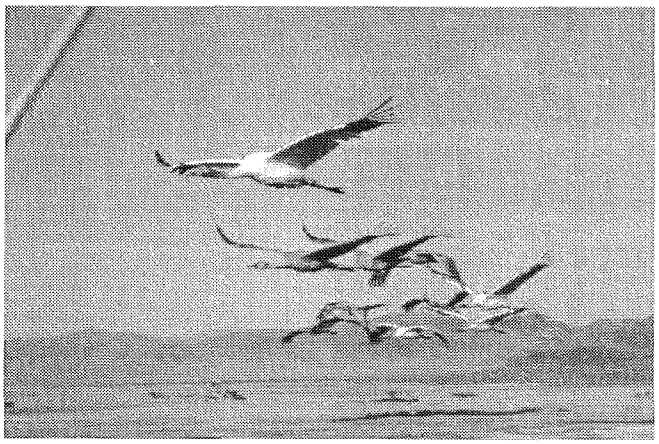

Fig. 5. Fledged juveniles were exercised in daily flights behind the UL aircraft. (Photo by Kent Clegg.)

only a few days apart were reared in species-specific subgroups (i.e., separate pens) to promote imprinting to their own species. The caretaker did not wear a crane costume. Horwich (1996:117) noted that sexual imprinting can be appropriate in captive-reared birds if they are introduced to their own species during the sensitive period. The cranes in this study were raised in species-specific groups throughout the sensitive periods described by Horwich (1996) as mentioned later in the Discussion.

Sibling aggression, documented by Archibald and Lewis (1996), was avoided by not placing chicks of considerable size difference in the same group. In addition, if a chick was behaving aggressively toward another chick(s), it was removed from the group. The problem chick was then fed all it could eat, exercised, and put back with its group after dark when chicks peacefully slept huddled together. If a chick continued to attack other chicks on subsequent days, the tip of its beak was clipped to discourage pecking.

Training of Cranes

Beginning when the chicks averaged 20 days old, the ATV was used to condition them to motor noise and to lead them. Occasional UL flights were made over the pens to help accustom chicks to the aircraft. After the chicks averaged 40 days of age, the UL was parked next to the pen with the engine idling. The birds were coaxed near the aircraft until they were comfortable with the engine noise. This conditioning activity continued outside the pen. The ATV was used to lead the birds in flight until they became sufficiently strong and maneuverable to follow the taxiing, and later, the flying UL (Fig. 5).

Training flights occurred each morning to different locations in the valley. Landings were made in unfamiliar areas; birds were allowed to forage and rest, and then were flown home. Flights terminated on the Clegg ranch and the birds were left to roam outside their pens for several hours.

Monitoring

Before migration, each crane was tagged with a leg-band-mounted, battery-powered, VHF radio transmitter (Advanced Telemetry Systems, Isanti, Minnesota) with an operational life of 1 year. In January 1997, satellite transmitters were placed on 2 sandhill cranes surviving from the 1995 migration and on 2 from the 1996 migration. These cranes were captured by night-lighting (Drewien and Clegg 1992). Satellite transmitters (Microwave Telemetry, Columbia, Maryland) were also placed on 2 of the whooping cranes 21 October 1997, after arrival at BdANWR and before release into the wild. These transmitters weighed 29 g (ca 50 g with leg band) and had an expected life of 285 days. Bright yellow leg bands (7.5-cm high) with black numbers were placed on each bird.

Migration

We used a Dragonfly UL (high wing, push propeller, tri-axis control, open cockpit, with a minimum and maximum air speed of 32 to 96 km/hr, and a fuel capacity sufficient for 2–3 hr aloft) to lead the cranes south. A Rans S7 experimental aircraft (high wing, maximum air speed 160 km/hr), accompanied the migration to monitor flight conditions ahead of the birds, to look for suitable landing sites, and to protect the cranes from attacks by golden eagles. The ground crew consisted of 4 or 5 individuals operating 4 vehicles. Landing locations were selected when the birds became tired, night approached, fuel supplies were low, weather became unfavor-

able, or when the cranes scattered either due to golden eagle attacks or the approach of unfamiliar aircraft.

The pilots typically had radio contact with each other and with the ground crew. One pickup truck towed an aircraft trailer used to transport a portable crane pen, ATV, camping gear, and other equipment. A second pickup truck towed a utility trailer used to transport cranes. A van and truck were used as chase vehicles to follow beneath the aircraft. Birds were usually penned at midday and overnight to protect them from predators (Fig. 6). Six panels (4.2 m x 1.8 m) tied together, and covered with netting, provided a pen with an area of 35 m^2. One or more members of the ground crew camped by the pen each night. In some situations, wetlands were available so the birds could feed and roost in water. On other occasions, surface water was not available near landing sites and the birds were penned in uplands. They were offered food and water 2 to 3 times daily.

Activities at the Release Site

Field corn was knocked down by BdANWR personnel to make it readily accessible to wild cranes before the UL cranes arrived. This practice was designed to encourage the UL cranes to remain on the refuge during the period of transition from human association to integration with wild sandhill cranes and to encourage the UL cranes to avoid adjacent private lands where crane hunting occurs. Sandhill crane hunters must have a special permit in the Middle Rio Grande Valley. Each hunter was given a flier describing the research, the birds' bright leg markings, and the radio transmitters and inviting cooperation in protecting the birds.

After the UL cranes arrived at BdANWR, the aircraft and familiar vehicles were removed from the vicinity. The UL cranes were encouraged to associate with the wild cranes so they would learn appropriate behavior for survival at the winter site. To promote that association, the crane decoy or the ATV (objects with which they had previously associated on the Clegg Ranch) was left where wild cranes would come to feed on knocked-down field corn. KRC remained at the refuge for approximately 10 days to monitor the birds and to ensure that they integrated with the wild sandhill cranes and adopted an appropriate water roosting pattern. The UL cranes were monitored daily through the winter months at BdANWR.

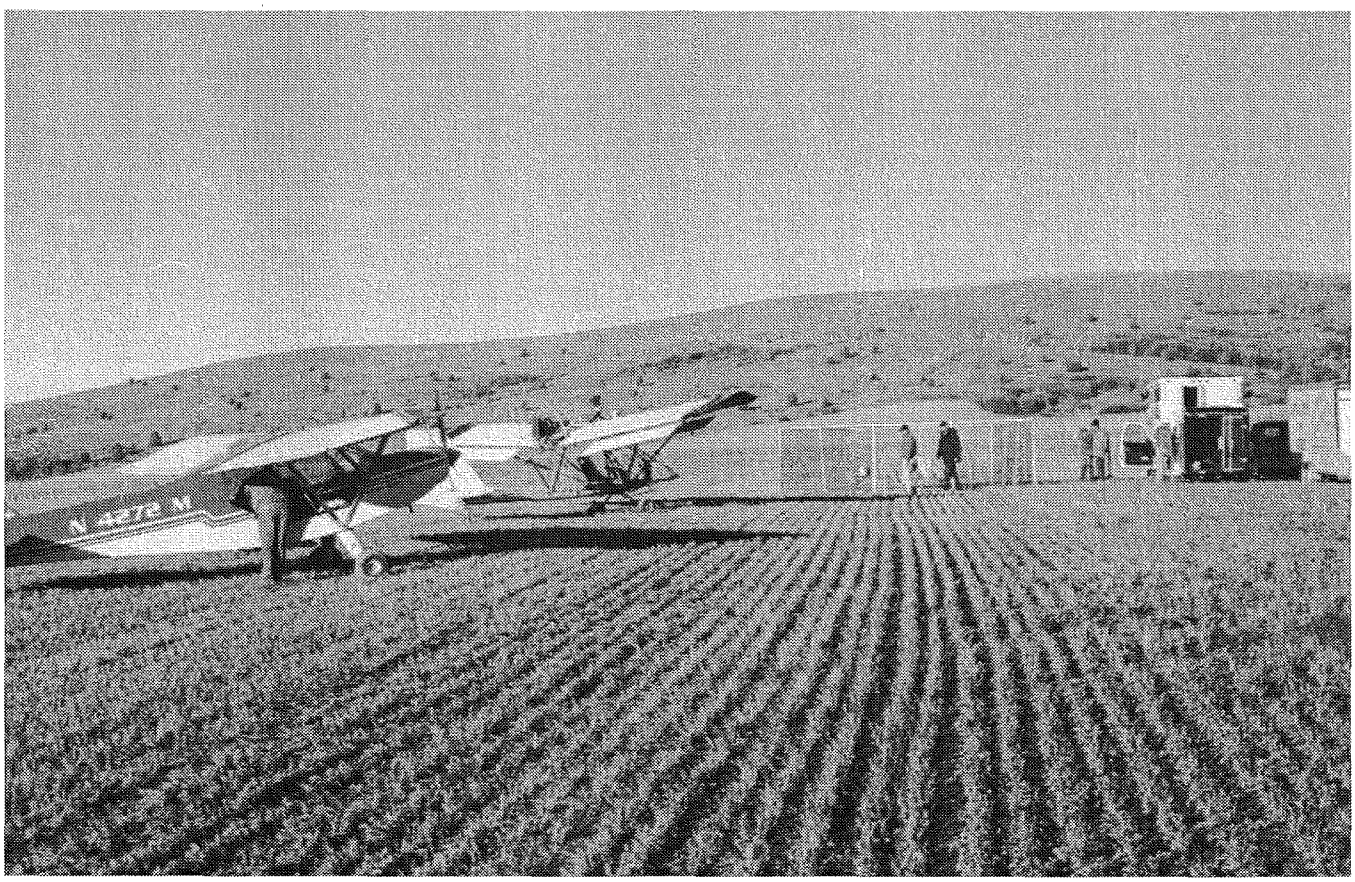

Fig. 6. Rans S7 experimental aircraft, Dragonfly UL, portable pen, chase vehicles, and aircraft trailer (left to right) used in the 1997 migration. (Photo by James C. Lewis.)

RESULTS

Rearing and Training

Isolation rearing, as presently practiced at most captive facilities, involves rearing a single chick in each pen. One of the benefits of group rearing is reduced cost, fewer pens are required and caretaker labor is reduced. Seven whooping cranes and 9 sandhill cranes fledged under the care of 2 caretakers plus periodic health checks by a veterinarian. Chicks of both species were robust and larger than chicks of similar age at Patuxent (G. H. Olsen, Patuxent, personal communication), perhaps due to the more natural diet and more extensive exercise regimen at the Clegg Ranch. The fledging success rate of 80% (16 of 20) compared favorably with the 75% rate reported for rearing of whooping cranes at Patuxent (Ellis and Gee 2001) and 80% for sandhill cranes in the last few years (J. M. Nicolich, Patuxent, personal communication).

Fledged cranes were trained to follow the ATV in flight. During flight, 1 whooping crane began showing evidence of a breathing disorder. Its condition deteriorated over 2 weeks, and it died of aspergillosis (*Aspergillus* sp.) at age 82 days. In the initial flights with the UL, only a few birds would follow and then for distances of only 100–200 m. Following behavior increased over several days until all were forming in lines off the aircraft's wings; thereafter, the length of the flights increased. At daybreak 27 September, 2 whooping cranes were found in their pen fatally injured. They may have been disturbed by coyotes at night or were injured when they flew into the pen wall on their own initiative. Before migration, a dominant male sandhill seemed to become bored with the training flights and would return prematurely to the ranch, drawing other cranes with him; he was separated from the group during subsequent flights.

Migration

The migration of 4 whooping cranes and 8 sandhill cranes began 13 October and ended 21 October (Table 1) with weather conditions generally favorable throughout. The 8.5-day migration (Fig. 7) occurred more rapidly than the 11 and 16 day migrations of the previous 2 years.

Difficult mountain flying conditions and golden eagles were the main problems encountered. Ground speeds ranged from 36 to 92.6 km/hr depending on tail and head winds. Average flight speed was 52.5 km/hr at an average altitude of 300 m above ground level. Daily flight distances ranged from 27-185 km. UL sandhill crane 51 was injured when it collided with the propeller guard during migration and had to be euthanized.

Table 1. Migration history of UL cranes flying from Grace, Idaho, to Bosque del Apache National Wildlife Refuge, New Mexico, October 1997.

Date (Oct)	AM/PM	Duration (hr)	Destination	Distance (km)
13	AM	0.16	N of Preston, Id.	37.2[a]
14	AM	2.0	Pass S of Paradise, Ut.	99.2
	PM	1.0	S of Morgan, Ut.	48.0
15	AM	2.0	Indian Creek, Strawberry Pass, Ut.	104.0
	PM	1.2	NNW Helper, Ut.	38.4
16	AM	2.7	Moab, Ut., airport	176.0
17	AM	2.5	Dove Creek, Colo.	131.2
	PM	0.2	Cahone, Colo.	16.0
18	AM	2.3	Newcomb, N.M.	132.8
	PM	0.8	SE Tohatchi, N.M.	52.8
19	AM	2.0	Airport, Grants, N.M.	102.4
	PM	0.4	San Fidel, N.M.	25.6
20	AM	2.0	Sevilleta NWR, LaJoya, N.M.	105.6
21	AM	1.0	Bosque del Apache NWR, N.M.	64.0
Total		20.3		1,133.2

[a] Flown 3.2 km, driven 34 km, see text.

Two single eagles attempted to attack UL cranes on 15 October but were chased away by the Rans UL. One eagle attacked early 16 October, injuring whooping crane 77. A veterinarian treated it for 2 deep cuts in the thigh; it was hauled in a trailer during the remaining migration. Preemptive actions by E. Spaulding in the Rans UL discouraged 1 eagle from attacking later the same morning and discouraged groups of 3 and 2 eagles from attacking the morning of 17 October. Two other persistent eagles attacked unsuccessfully in late afternoon 17 October. The pilots interrupted the attacks by intercepting the eagles, and E. Spaulding shot shell crackers in their direction to frighten them. The cranes responded when unfamiliar aircraft approached in the same manner as they would to an eagle attack: namely, they flew under the Dragonfly UL or scattered.

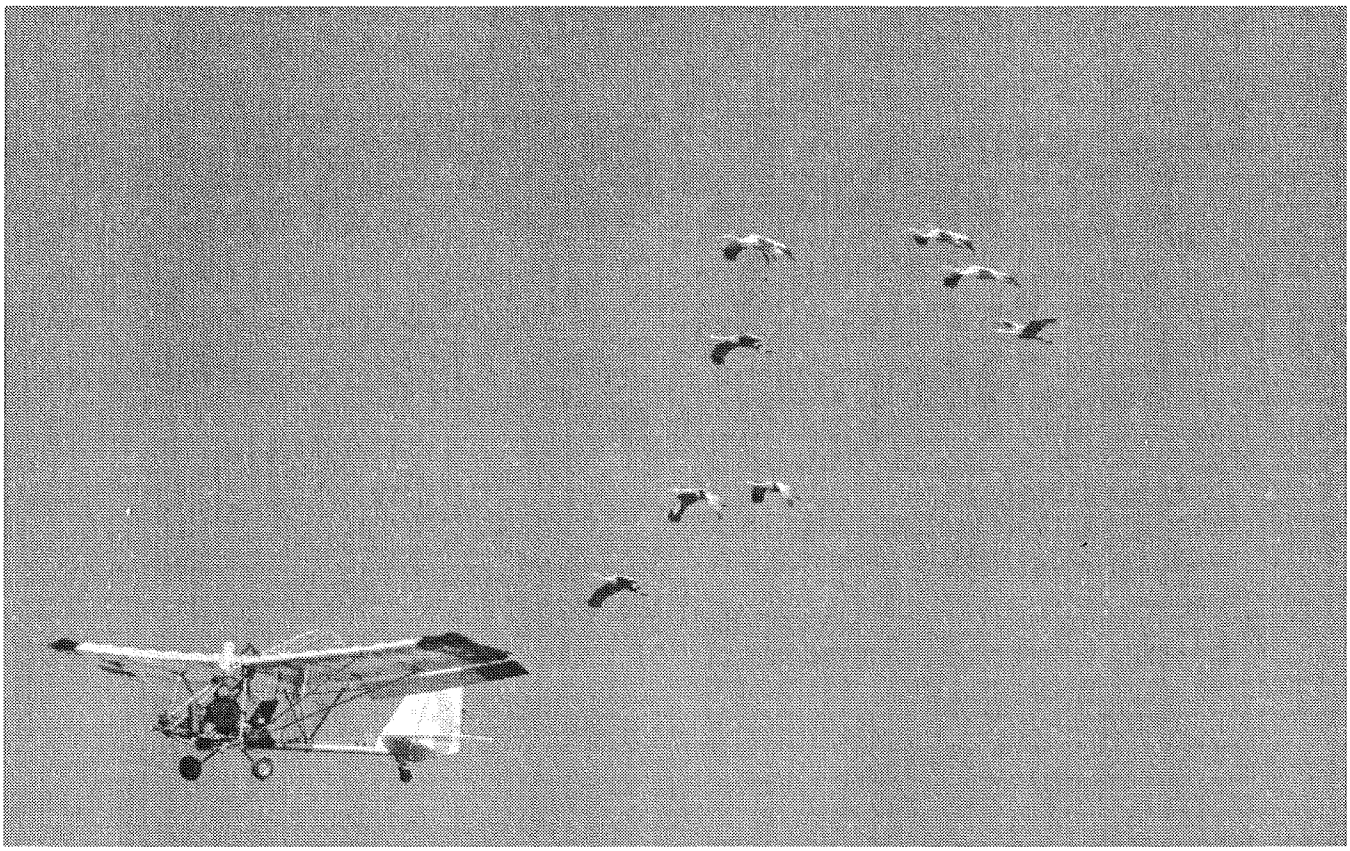

Fig. 7. Dragonfly UL and cranes approaching landing in the 1997 migration. (Photo by James C. Lewis.)

Adaptation to the Wild at the Wintering Site

Completely weaning the captive-reared cranes from association with humans is crucial to releasing these birds to the wild. Our foremost concern was to ensure that the cranes roosted in water at an appropriate site, safe from predators, upon their arrival at BdANWR. About 1600 hr on 21 October, KRC used the ATV and his brood call to lure the research birds away from the wild flock. With the exception of UL whooping crane 77, which had not fully recovered from the eagle attack, the UL cranes flew above the ATV as he led them to the edge of the Rio Grande. There they could see the familiar crane decoy on a sandbar island. As the ATV halted beneath the canopy of trees, the cranes continued forward and landed on the island where corn had been spread in the vicinity of the decoy. Wild cranes began landing on the island within 1 hr, giving the UL cranes further stimulus to roost overnight in the river. For the next 3 mornings and evenings, the UL cranes were attracted to and from the roost by KRC until they developed daily movement patterns similar to the wild cranes.

UL whooping crane 77, injured earlier by an eagle, would not leave the agriculture field on 21 October and was captured and placed in a trailer overnight. The next morning, 77 was moved to a Rio Grande island sandbar where it would be protected from coyotes and bobcats while it healed. Food was provided there. UL 77 healed sufficiently to leave the river roost on its own initiative the morning of 28 October and flew to the feeding fields with other cranes.

UL sandhill crane 53 was shot 26 October (5 days after release to the wild) by crane hunters when it left BdANWR with wild sandhill cranes. To our knowledge, no other UL cranes left BdANWR at this time.

All UL cranes were traveling between the roost and feeding fields on their own initiative by 1 November. When together in group situations, the juvenile whooping cranes were dominant to wild adult sandhill cranes, but solitary juvenile whooping cranes were generally submissive to adult sandhill cranes. The reactions of UL cranes to coyotes were like those for the wild cranes; they alertly watched it and moved off as it approached.

A cross-fostered (c-f) (Drewien and Bizeau 1978) adult whooping crane (Patuxent 16) arrived at BdANWR on 2 November and joined the UL cranes on the roost. On 5

November, 2 UL whooping cranes joined Patuxent 16 for 3 hr in an agriculture field. Through the use of the decoys it was possible to manipulate where the whooping crane chicks would land on subsequent mornings. By placing the decoys in areas frequented by Patuxent 16, it was possible to encourage the association between the chicks and the adult. Later the decoys were removed and the chicks continued to associate with, and occasionally unison called with, Patuxent 16. The association between the UL whooping cranes, Patuxent 16, and the adult whooping crane X sandhill crane hybrid (Lewis 1995) increased as winter progressed and exceeded any association between whooping cranes and sandhill cranes. The juvenile whooping cranes seemed to recognize Patuxent 16 as conspecific and vice versa.

From 3 November through 26 January the UL sandhill cranes and whooping cranes fed daily in an agriculture field where corn had been knocked down near the whooping crane decoy. Patuxent 16 was landing there also and staying with the juvenile birds until the food was consumed each morning. Patuxent 16 would accept the presence of the juvenile UL cranes but chased away any other cranes that approached. The whooping crane decoy was removed the third week of January so it would not inhibit the cranes from migrating northward when the wild birds started leaving.

Two UL whooping cranes died in November and December. Whooping crane UL 88 was killed by a coyote about 11 November (21 days after release to the wild). The other UL cranes arrived from the river roost singly and from scattered locations on the morning of 12 November as though disturbed by a predator the previous night. The remains of UL 88 were found 12 November; it may have tried to roost in shallows and a pool bordering the Rio Grande where it was vulnerable to predation. The bird's transmitter was found in salt cedar (*Tamarix pentandra*) bordering the river. The buried leg of whooping crane UL 32, killed by a bobcat, was found on 3 December (43 days after release) along the Rio Grande in an eroded gulch. The satellite tag was transmitting from the vicinity but could not be found.

Three coyotes were observed swimming the river and flushing cranes from the roost at dawn 7 December. The 2 surviving UL whooping cranes appeared to be in jeopardy roosting on the Rio Grande. We encouraged them to change roosting sites by frightening them from a feeding field just as flocks of sandhill cranes were leaving to roost in a water impoundment.

Roosting in the impoundment became a problem by 28 December because the pool was visible from a public viewing site. Many people were viewing and photographing the whooping cranes and the whooping cranes began separating from the wild cranes and moving towards the people. The UL whooping cranes were then hazed to a roosting impoundment isolated from people. Thereafter, they used various roost sites on the Rio Grande and in impoundments depending on the amount of predator disturbance, behavior also typical of wild cranes. They often foraged near the public tour loop of BdANWR but never interacted with people. In mid-February, the 2 UL whooping cranes were still associating regularly with Patuxent 16 and the hybrid.

Spring 1998 Migration

The 2 UL whooping cranes, 2 UL sandhill cranes, and the hybrid departed BdANWR 5 March 1998 (Fig. 8). On 10 March, 9 radiotagged cranes were confirmed in the San Luis Valley of Colorado, including UL whooping cranes 77 and 59, 5 UL sandhill cranes from 1997, and 2 UL sandhill cranes from 1996. The UL cranes were still in the San Luis Valley 29 March.

On 8 April, UL whooping cranes 59 and 77 spiraled high into the sky with a large flock of sandhill cranes as though initiating migration. They flew about 24 km north before

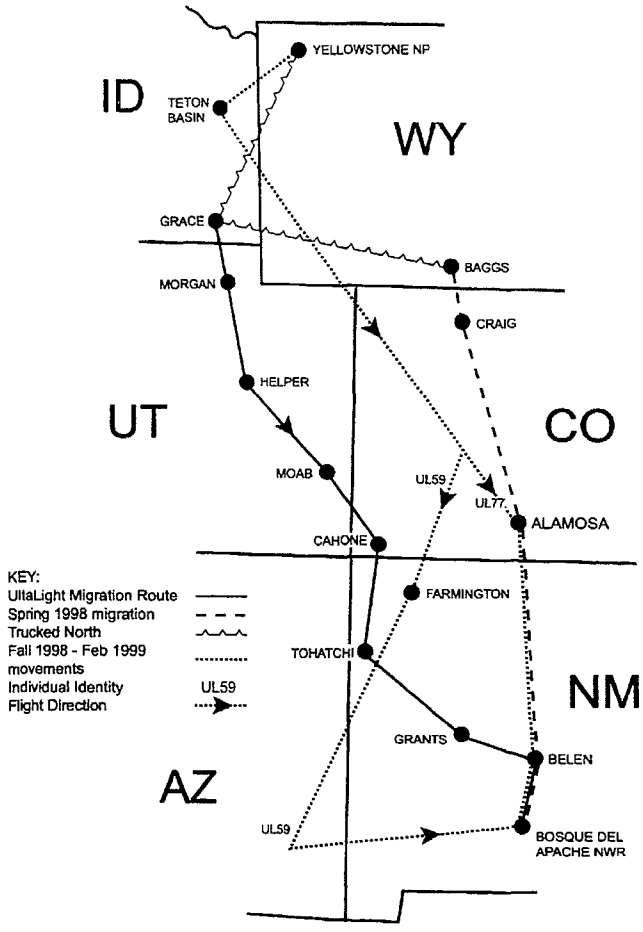

Fig. 8. Movements of UL whooping cranes, autumn 1997 through February 1999.

returning alone. The UL whooping cranes rode thermals up for the next 3 days spending an average of 1.2 hr circling before migrating on 11 April. They were among the last cranes to depart the area. They were radiotracked 128 km until their signals could no longer be heard and were last seen with 7 sandhill cranes.

The satellite data indicated a whooping crane near Rock Springs, Wyoming, on 13 April, but the crane could not be located during a ground search. A satellite reading on 17 April indicated the bird was 112 km southeast of Rock Springs near Craig, Colorado. It was found 18 April in a 4-ha wet meadow with 2 sandhill cranes. They were using a hazardous location where a power line crossed the water. The second UL whooping crane was reported near Baggs, Wyoming, in a small meadow with 3 wild juvenile sandhill cranes, a site unsuitable for long-term occupancy and vulnerable to disturbance by humans. UL whooping cranes 77 and 59 were recaptured at their roosts by night-lighting (Drewien and Clegg 1992) on 24 April 1998, were confined a few days at the Clegg ranch, and then on 1 May 1998, they were transferred to Slough Creek in Yellowstone National Park (YNP), a release area selected by YNP staff. Slough Creek was easily accessible to YNP visitors and a popular area for viewing wolves. The UL whooping cranes initially associated with a wild sandhill yearling. Predators in the area were 2 nesting pairs of golden eagles, coyotes, a pack of wolves (*Canis lupus*), and grizzly bears (*Ursus horribilis*).

A rancher near Fruita, Colorado, reported 3 banded sandhill cranes on his property on 22 April 1998: 1 was dead. The carcass of 1997 UL sandhill crane 55 (183 days after release) was found bordering an electric fence that was hooked to 110 V. It appeared the crane had been electrocuted.

Movements Subsequent to Spring 1998

After the tourist season began in June, the UL whooping cranes at YNP became an attraction for photographers, birders, and tourists. A tour guide from the Yellowstone Science School took groups to the vicinity almost daily to see the cranes and wolves. With the frequent, nonthreatening presence of humans, the UL cranes became less wary and allowed humans to approach within 40 m. A decision was made to capture and move them to an area isolated from the public.

UL 59 was captured by KRC 20 July and transported by helicopter to Bechler Meadows in the southwest corner of YNP where it was quickly joined by whooping crane Patuxent 16 which typically summers in the vicinity. UL 77 was too wary to capture and spent the rest of the summer around Lower Slough Creek avoiding people and associating with a pair of sandhill cranes.

Before the fall migration, whooping cranes c-f Patuxent 16, UL 77, UL 59, and the hybrid staged in the Teton Basin west of Driggs, Idaho, where KRC observed them 22 September 1998. The UL whooping cranes were together; Patuxent 16 and the hybrid were nearby. The UL whooping cranes and the hybrid migrated from the Teton Basin 27–29 September.

UL 59 was reported near Farmington, New Mexico, from 25 October to 2 November 1998. Later there were unconfirmed reports of a whooping crane in the Wilcox Playa area of southeastern Arizona. UL 59 may have wintered in that area or passed through it to winter in Mexico. It was sighted 35 km north of Wilcox Playa, Arizona, by Arizona Game and Fish Department personnel on 8 February 1999.

UL 77, c-f Patuxent 7, the 5 surviving 1997 UL sandhill cranes, and the hybrid were observed in the San Luis Valley of Colorado by KRC in mid-October 1998. UL 77 and Patuxent 7 were frequent associates. UL 77, Patuxent 16, and the hybrid subsequently wintered at BdANWR where the UL whooping crane was first observed 7 December. Five 1997 UL sandhill cranes were also confirmed wintering at BdANWR.

Research funds for monitoring the UL cranes were exhausted in early 1999. Subsequent sightings were by U.S. Fish and Wildlife Service (FWS) personnel, infrequent surveys of KRC, and chance sightings by competent observers. UL whooping crane 59 flew from Wilcox Playa, Arizona, to BdANWR and rejoined UL whooping crane 77 at BdANWR, arriving on 14 February 1999, where they were observed by biologist J. Taylor of the FWS. They were constant associates from then through their departure northward on 12 March. Five 1997 UL sandhill cranes were tracked north into the San Luis Valley during spring migration 1999, but UL whooping cranes 59 and 77 were never seen there.

Next UL whooping cranes 59 and 77 were seen 11 April at Deer Creek Reservoir near Heber City, Utah. This leads to the speculation that they may have flown north along their original, UL-led migration route of October 1997: Heber City is 160 km west of the traditional migration route used by most wild sandhill cranes of the Rocky Mountain Population (Drewien and Bizeau 1974, Fig. 1). In retracing the 1997 migration route, the whooping cranes would have been 140 km west of the San Luis Valley.

The scavenged remains of UL whooping crane 77 was found 29 August 1999 (about 670 days after wild release) north of Randolph, in north central Utah. Ranchers reported that it had been in the area most of the summer and was limping. The cause of death is unknown.

UL whooping crane 59 was seen in Arbon Valley, 10.5 km south of Crystal Summit, Idaho, on 16 May 1999 and at Grays Lake NWR on 2 June, where it spent the summer. M. Fisher, refuge manager at Grays Lake, reported that UL 59

departed about 1 September. On 20 October 1999, UL 59 was seen by FWS biologist M. DeLeon, near Ouray, Utah, with an unidentified c-f whooping crane.

The conventional radio transmitters that were attached in October 1997 were still functioning on 5 sandhill cranes as they migrated north in March 1999. This equipment lasted at least 18 months. The satellite telemetry equipment lasted approximately 1 year. Two 1997 UL sandhill cranes were observed briefly at BdANWR 18 Nov 1999.

DISCUSSION

UL cranes were released at BdANWR using the abrupt method (Nagendran et al. 1996) without acclimating them to the release site. However, these cranes were prepared for wild release during their daily outings on the Clegg Ranch where they functioned as an independent flock in a semi-wild environment. UL cranes were also strong fliers, capable of prolonged flight. With the exception of trucked cranes (Ellis et al. 1997), most other captive-reared cranes had only limited flying experience in flight pens before their wild release. The activities of the UL cranes upon release were also orchestrated by KRC to maximize their security and promote their immediate association with wild cranes. These actions eliminated the need to pen cranes at the release site for 2 weeks or more as has been the normal practice in gentle releases (Nagendran et al. 1996).

"Foot and leg problems are common during captive rearing" (Olsen and Langenberg 1996:101). These authors note that the frequency of such problems can be reduced by proper attention to diet, adequate exercise, proper substrate, controlled weight gain, and proper handling methods. Leg and foot problems were not encountered in the UL chicks, reared on a rough substrate (much like chicks would encounter in the wild), exercised frequently, and given access to nutritious commercial and natural foods.

Sibling aggression has been documented in greater sandhill cranes and whooping cranes (Archibald and Lewis 1996). At most facilities, chicks are reared in individual pens. Aggression is most evident the first 10 days after hatching. UL sandhill crane and whooping crane chicks were reared in species-specific groups, thereby reducing pen costs and labor. This project effectively demonstrated the feasibility of group rearing sandhill cranes (Clegg et al. 1997) and whooping cranes. Keeping the chicks well fed and exercised are important to minimizing aggression that causes injuries or death. Access to live prey may also reduce aggression.

Group rearing the cranes in semi-wild circumstances on the Clegg Ranch helped prepare them for life independent of a caretaker when they arrived at BdANWR. Cranes are gregarious and the group functioned like a flock, aiding individual birds to find food and avoid predators. The UL group was accustomed to functioning independently without a caretaker present. After release to the wild, the UL cranes quickly joined the wild cranes.

Subjectively, it appears that group rearing promotes appropriate sexual imprinting; however, the length of our research did not allow us to experimentally confirm this hypothesis. Horwich (1996:119) discussed imprinting stimuli and noted cycles in parent-young attachment among cranes. He noted that appropriate sexual imprinting can be induced in captive-reared birds if they are introduced to their own species during the sensitive period. After the initial attachment at hatching, there is a period of gradually increasing independence from the parent. At fledging there is a reattachment period when young cranes again stay close to the parent. Horwich (1996) noted that this reattachment seems equivalent to the sexual imprinting period. Among chickens this reattachment period can reverse any improper sexual imprinting that occurred earlier in development (Vidal 1976 *in* Horwich 1996).

A second reattachment cycle is evident in cranes at the time of migration. The UL cranes were reared in species-specific groups from hatching through migration. Thus, they were in close association with conspecifics throughout the imprinting cycles described by Horwich (1996). Our field observations indicate appropriate recognition of conspecifics by the UL whooping cranes. The UL whooping cranes associated more with other UL whooping cranes, c-f whooping cranes, and the hybrid than they did with the more numerous sandhill cranes; this behavior continues to date with the lone UL whooping crane survivor.

Water-roosting behavior is essential to survival of captive-reared cranes after they are released to the wild. Without water-roosting opportunities in captivity, whooping cranes did not quickly learn water-roosting after release in the wild and were vulnerable to predation (Nesbitt et al. 1997). UL whooping cranes and sandhill cranes were night roosting in water in captivity by the time they fledged. They quickly learned to use appropriate water roosting sites at BdANWR.

R. C. Drewien (Hornocker Wildlife Institute, personal communication) noted that juvenile c-f whooping cranes were harassed by adult sandhill cranes and sometimes kept at the periphery of a flock. Only the protective actions of the foster parent sandhill cranes allowed the young whooping cranes to benefit from flock security. The UL whooping cranes and sandhill cranes were exercised together on the Clegg Ranch after the sandhill cranes averaged 29 days old. The UL whooping cranes were larger and dominant over the younger sandhill cranes. Association of these 2 captive-reared species in Idaho was designed to promote flocking of UL whooping cranes with wild sandhill cranes on the wintering grounds and, thereby, to expedite the UL cranes' transition to wild behavior. Association between the captive-reared and wild

cranes seemed beneficial when the UL cranes were released at BdANWR. As a group, the UL whooping cranes quickly associated with flocks of wild sandhill cranes and, as a consequence, shared food resources and were safer from predators. When the juvenile UL whooping cranes were together, each was dominant to adult sandhill cranes. However, adult sandhill cranes were dominant to some UL whooping cranes when separate from their cohorts.

Urbanek and Bookhout (1992: Table 2) listed 17 studies in which captive-reared sandhill cranes were released to the wild in migratory and nonmigratory situations. In the studies cited, the birds were parent-reared, costume-reared, partial-costume-reared, or hand-reared without costumes. In the 8 studies involving release of more than 2 cranes in a migratory situation, the average minimum survival for 8–12 months ranged from 8% to 94%. Of our 1997 group-reared UL cranes, 64% (7 of 11) were still alive 18 months after release (Table 2). We believe survival can be increased in future experiments.

Because wild juvenile cranes are accompanied by their parents, our UL cranes probably were more vulnerable to predators. Wild and captive adult cranes generally spend more time in vigilant behavior and less time feeding and resting than juvenile cranes (Alonso and Alonso 1991, Drewien et al. 1997). Chicks accompanied by alert parents gain some security from predators. The juvenile UL cranes probably gained some security through association with adult wild cranes but not as much security as exists with the parent-chick bond.

The migration from Idaho to New Mexico required only 8.5 days compared to 11 and 16 days in the 2 previous UL migrations. An important factor in the faster migration was the decision to favor landing sites at high elevations like mountain passes. In 1995, the first year of migration, valley landing sites were preferred where the cranes could rest and feed in wetlands. These choices meant the cranes had to make ponderous climbing flights to cross over mountains and reach altitudes where flight was easier. Such flights sometimes meant the cranes were flying into, instead of above, down-slope winds that greatly increased energy required for flight. When the cranes took flight from high points, they were able to reach favorable flying altitudes with minimal expenditure of energy. The average daily flight distance in 1997 was 133.8 km compared to 109.5 km in 1995.

Summer locations of 38 yearling and 36 adult c-f whooping cranes were noted by Drewien et al. (1989 unpublished); 95% summered within 200 km of Grays Lake NWR, where they hatched. The UL cranes in their first and second springs returned to summering areas appropriate for their natal area; 2 UL sandhill cranes even returned briefly to the Clegg Ranch in the springs following their release. The ability of these cranes to home back to the geographic area where they were raised may involve more than backtracking the route followed in their first southward migration, randomly following other wild birds, or navigating by prominent geographic features.

Table 2. Status of 1997 UL cranes released to the wild, 21 October 1997, BdANWR.

ID	Date last sighting/ recovery	Time survived in wild	Status
SC53	26 Oct 97	5 days	Shot by hunter
WC88	11 Nov 97	21 days	Killed by coyote
WC32	3 Dec 97	43 days	Killed by bobcat
SC55	22 Apr 98	183 days	Electrocuted
WC77	29 Aug 99	670 days	Dead, cause unknown
SC57	3 Mar 99	18 months +	Alive spring 1999
SC52	3 Mar 99	18 months +	Alive spring 1999
SC54	3 Mar 99	18 months +	Alive spring 1999
SC56	18 Nov 99	24 months +	Alive fall 1999
SC58	16 Jan 00	26 months +	Alive winter 1999
WC59	7 Feb 00	27 months +	Alive winter 1999

Migration of large birds with UL aircraft has some inherent dangers to the pilots and birds. The plane can only be flown when winds are low; storms prevented flying for 6 days in 1996. Some cranes were transported in a trailer for part of the migration in each of the research years. Those individuals seemed to perform equally well in choice of summer sites and finding their way back to the winter site. The next proposed phase of our migration research was a combination of leading the birds with the UL at a few points along the migration route but hauling them in a trailer most of the distance. If this practice works as well as flying the entire migration route, it would reduce safety hazards to the pilot, cranes, and aircraft, reduce costs, and reduce dependence on suitable flying weather.

For at least the first year following release to the wild, UL cranes should be kept from frequent association with humans. The UL whooping cranes behaved like wild cranes, but frequent, nonthreatening contacts with people at YNP soon resulted in the UL whooping cranes becoming less cautious towards humans: they would allow people to approach within 40 m before retreating. When the cranes

passed between 2 wetlands, they also walked within 25 m of stationary humans waiting for photo opportunities. Wild behavior is enhanced in cranes by encouraging them to use summer habitats isolated from humans and by negative contacts with people (i.e., chasing the cranes).

Yearling c-f whooping cranes spent their summers widely distributed throughout the summer range and occasionally along the spring migration route (Drewien et al. 1989 unpublished). These summer sites were frequently not used by the same individuals in subsequent summers. UL sandhill cranes of 1995 and 1996, exhibited the same summering behavior as yearling and 2-year-old c-f whooping cranes. When reintroducing an endangered crane species, a manager will be dealing with small numbers of individuals. Most UL cranes returned in subsequent winters to utilize the same areas where they were released after their first migration. The potential for wild-released birds to survive, pair, and reproduce will be enhanced if they can be influenced to concentrate in specific secure summer habitats, just as they had been influenced to concentrate in a favorable winter habitat.

The FWS proposed in 1996 and finalized in 1997 a Federal Rule designating whooping cranes of the Rocky Mountain West as Experimental Nonessential (U.S. Department of Interior 1996, 1997). The primary purpose of the Rule was to allow greater management flexibility for research including periodic capture, handling, radiotagging, marking, movement, and intensive monitoring. Research to enhance pairing of c-f whooping cranes indicated that individuals captured in late spring and transferred to Grays Lake NWR would remain there for the summer (Drewien et al. 1989 unpublished, U.S. Fish and Wildlife Service 1994). Research proposed for the 1997 UL cranes included manipulating where they summered by capturing the cranes when they reached the summer range and moving them to suitable, secure summer habitat. It is essential that similar flexibility be programmed into each release project. In the Results section, it was noted that on 24 April 1998, UL whooping cranes 77 and 59 were using unfavorable, hazardous sites. They were captured at their roosts by night-lighting and moved to YNP. These translocations were to be the first stage of testing a technique to predetermine where the UL cranes would summer. If the cranes failed to return to the preferred summer site as 2-year-olds, the intent was to capture and move them again to see whether they would eventually return on their own to the preferred summer site.

MANAGEMENT IMPLICATIONS

This research tested techniques for introducing an endangered crane species where migration is required and where another wild crane species is established. The technique utilizes the resident wild crane species to help the introduced cranes to survive. Whooping cranes can be group-reared, trained to follow experimental aircraft, and will adopt wild behavior on a wintering site in the same manner as captive-reared sandhill cranes. Group rearing the cranes in a semi-wild state helped prepare the birds for integration to the wild when they arrived at BdANWR. Not only were they strong flyers, but they were also accustomed to flock associations, were used to finding food independently, and were experienced at roosting in water each night.

Basic techniques of training, migration, and introduction to the wild were suitable and show promise for improved survival in future reintroductions. We believe group rearing produces cranes that are properly sexually imprinted. However, the project was not continued long enough to prove that sexually mature UL cranes would pair with conspecifics.

ACKNOWLEDGMENTS

For financial support we thank the Canadian Wildlife Service, Friends of the Bosque, Patuxent, National Fish and Wildlife Foundation, Pacific Corporation, Portneuf Audubon Club, Sierra Club, Spirit of Utah Wilderness, Turner Endangered Species Fund, FWS, Whooping Crane Conservation Association, Windway Capital Corporation (which provided funds through the International Crane Foundation), World Wildlife Fund-Canada, and World Wildlife Fund-USA. Personnel from Bear River NWR assisted in burying a power line bisecting the field in Idaho where cranes were being trained to fly. Staff of YNP assisted KRC in monitoring and transport of cranes during summer 1998.

JCL was National Whooping Crane Coordinator, U.S. Fish and Wildlife Service, until his retirement in March 1997. FWS allocated time for him to work on this project. Especial thanks are due M., P., S., D., and F. Clegg for their assistance in rearing and migration of the birds. The International Crane Foundation produced 3 whooping crane eggs for this research and Patuxent provided 6 eggs. Our thanks to G. F. Gee and his staff for their assistance while the whooping crane chicks were at Patuxent; H. Seitz and M. Kinloch provided assistance in the initial rearing, and G. H. Olsen provided health care for the young cranes at Patuxent and in Idaho. T. Kohler of Windway Capital Corporation transported the whooping crane chicks from Maryland to Idaho.

The authors also appreciate the substantial assistance of E. Spaulding who piloted a Rans S7 experimental aircraft during migration. S. MacBush provided an aircraft for locating cranes in summering areas and ground support and equipment during migration. NASA-Goddard Space Flight Center provided satellite transmitters and the associated monitoring capabilities. T. Stehn and S. Spaulding assisted in the ground crews during migrations. R. Garcia and L.

Rawinski, Alamosa/Monte Vista NWR, monitored the cranes while they were staging in southern Colorado in March-April. S. Scolari, M. Gallagher, and B. Hayes provided major assistance in monitoring the birds while they wintered at BdANWR. P. Norton, manager of BdANWR, and his staff provided housing and helped in many other ways. To all of these individuals we express our deep appreciation.

LITERATURE CITED

Alonso, J. C., and J. A. Alonso. 1991. Cost and benefits of flocking in wintering common cranes. Pages 271-276 *in* J. Harris, editor. Proceedings 1987 international crane workshop. International Crane Foundation, Baraboo, Wisconsin.

Archibald, G. W., and J. C. Lewis. 1996. Crane biology. Pages 1-29 *in* D. H. Ellis, G. F. Gee, and C. M. Mirande editors. Cranes: their biology, husbandry, and conservation. National Biological Service, Washington, D.C. and International Crane Foundation, Baraboo, Wisconsin, USA.

Clegg, K. R., J. C. Lewis, and D. H. Ellis. 1997. Use of ultralight aircraft for introducing migratory crane populations. Proceedings North American Crane Workshop 7:105-113.

Drewien, R. C., and E. G. Bizeau. 1974. Status and distribution of greater sandhill cranes in the Rocky Mountains. Journal of Wildlife Management 38:720-742.

_____, and _____. 1978. Cross-fostering whooping cranes to sandhill crane foster parents. Pages 201-222 *in* S. A. Temple, editor. Endangered birds: management techniques for preserving threatened species. University of Wisconsin Press, Madison, Wisconsin, USA.

_____, W. M. Brown, and E. G. Bizeau. 1989 unpublished. Whooping crane cross-fostering experiment. Hornocker Wildlife Research Institute, University of Idaho, Moscow, Idaho, USA.

_____, W. M. Brown, and E. G. Bizeau. 1992. Sandhill crane surveys in the northern interior highlands of Mexico. Proceedings North American Crane Workshop 6:174.

_____, and K. R. Clegg. 1992. Capturing whooping cranes and sandhill cranes by night-lighting. Proceedings North American Crane Workshop 6:43-49.

_____, W. L. Munroe, K. R. Clegg, and W. M. Brown. 1997. Use of cross-fostered whooping cranes as guide birds. Proceedings North American Crane Workshop 7:86-95.

Edwards, R., S. Brechtel, R. Bromley, D. Hjertaas, B. Johns, E. Kuyt, J. Lewis, N. Manners, R. Stardom, and G. Tarry. 1994. National recovery plan for the whooping crane. Report 6. Recovery of Nationally Endangered Wildlife Committee, Ottawa, Canada.

Ellis, D. H., B. Claus, T. Watanabe, R. C. Mykut, M. Kinloch, and C. H. Ellis. 1997. Results of an experiment to lead cranes on migration behind motorized ground vehicles. Proceedings North American Crane Workshop 7:114-122.

_____, K. R. Clegg, J. C. Lewis, and E. Spaulding. 1999. Golden eagle predation on experimental sandhill and whooping cranes. Condor 101:664-666.

_____, and G. F. Gee. 2001. Whooping crane egg management: options and consequences. Proceedings North American Crane Workshop 8:17-23.

Horwich, R. H. 1996. Imprinting, attachment, and behavioral development in cranes. Pages 117-123 *in* D. H. Ellis, G. F. Gee, and C. M. Mirande editors. Cranes: their biology, husbandry, and conservation. National Biological Service, Washington, D.C. and International Crane Foundation, Baraboo, Wisconsin, USA.

Lewis, J. C. 1995. Whooping crane (*Grus americana*). Number 153 *in* A. Poole and F. Gill, editors. The birds of North America. Academy of Natural Sciences, Philadelphia, Pennsylvania and American Ornithologists' Union, Washington, D.C., USA.

Nagendran, M., R. P. Urbanek, and D. H. Ellis. 1996. Special techniques, Part D: reintroduction techniques. Pages 231-240 *in* D. H. Ellis, G. F. Gee, and C. M. Mirande, editors. Cranes: their biology, husbandry, and conservation. National Biological Service, Washington, D.C. and International Crane Foundation, Baraboo, Wisconsin, USA.

Nesbitt, S. A., M. J. Folk, M. G. Spalding, J. A. Schmidt, S. T. Schwikert, J. M. Nicolich, M. Wellington, J. C. Lewis, and T. H. Logan. 1997. An experimental release of whooping cranes in Florida-the first three years. Proceedings North American Crane Workshop 7:79-85.

Olsen, G. H., and J. A. Langenberg. 1996. Veterinary techniques for rearing crane chicks. Pages 95 to 104 *in* D. H. Ellis, G. F. Gee, and C. M. Mirande. Cranes: their biology, husbandry, and conservation. National Biological Service, Washington, D.C. and International Crane Foundation, Baraboo, Wisconsin, USA.

Urbanek, R. P., and T. A. Bookhout. 1992. Development of an isolation-rearing/gentle release procedure for reintroducing migratory cranes. Proceedings North American Crane Workshop 6:120-130.

U.S. Department of the Interior, U.S. Fish and Wildlife Service. 1996. Endangered and threatened wildlife and plants; Proposal to designate whooping cranes of the Rocky Mountains as experimental nonessential and to remove whooping crane critical habitat from four locations. Federal Register Vol. 61:4394-4401 (Feb. 6).

_____. 1997. Endangered and threatened wildlife and plants; Final rule to designate whooping cranes of the Rocky Mountains as experimental nonessential and to remove whooping crane critical habitat from four locations. Federal Register Vol. 62:38932-38939 (July 21).

U.S. Fish and Wildlife Service. 1994. Whooping crane recovery plan. U.S. Fish and Wildlife Service, Albuquerque, New Mexico, USA.

Westerskov, K. 1950. Methods for determining the age of game bird eggs. Journal of Wildlife Management 14:56-67.